US006106661A

United States Patent [19]

Raeder et al.

[11] **Patent Number: 6,106,661**

[45] **Date of Patent: Aug. 22, 2000**

[54] POLISHING PAD HAVING A WEAR LEVEL INDICATOR AND SYSTEM USING THE SAME

[75] Inventors: **Christopher H. Raeder**; **Kevin D. Shipley**; **Peter A. Burke**, all of Austin, Tex.

[73] Assignee: **Advanced Micro Devices, Inc.**, Austin, Tex.

[21] Appl. No.: **09/074,892**

[22] Filed: **May 8, 1998**

[51] **Int. Cl.**^{7} **C23F 1/02**

[52] **U.S. Cl.** **156/345**; 438/691; 451/259

[58] **Field of Search** 156/345; 451/259; 438/691

[56] References Cited

U.S. PATENT DOCUMENTS

5,913,713 6/1999 Cheek et al. 451/41

Primary Examiner—Robert Dawson
Assistant Examiner—D. Aylward
Attorney, Agent, or Firm—Williams, Morgan & Amerson, P.C.

[57] ABSTRACT

A polishing pad having a wear level indicator and a polishing system employing the same is provided. A polishing pad, in accordance with one embodiment of the invention, includes a pad structure and an indicator, disposed in the pad structure, indicating the wear level of the pad structure. The pad structure may, for example, include a top pad and a bottom pad with the indicator being disposed in the top pad. The wear level may, for example, be a critical thickness of the polishing pad which indicates the end of the pad lifetime or which indicates the need to change polishing processing. The use of a wear level indicator allows for efficient and reliable pad wear level indication.

42 Claims, 3 Drawing Sheets

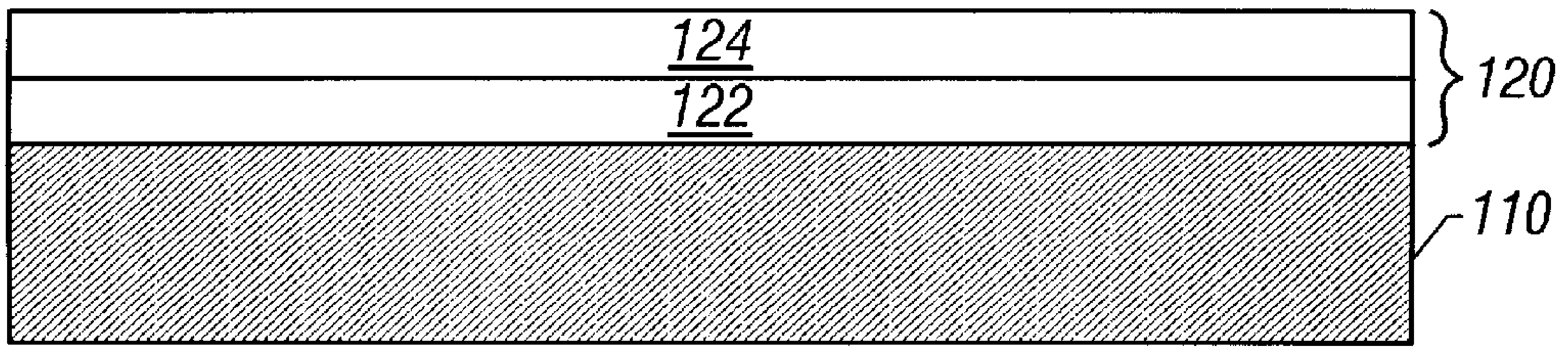

FIG. 1
(Prior Art)

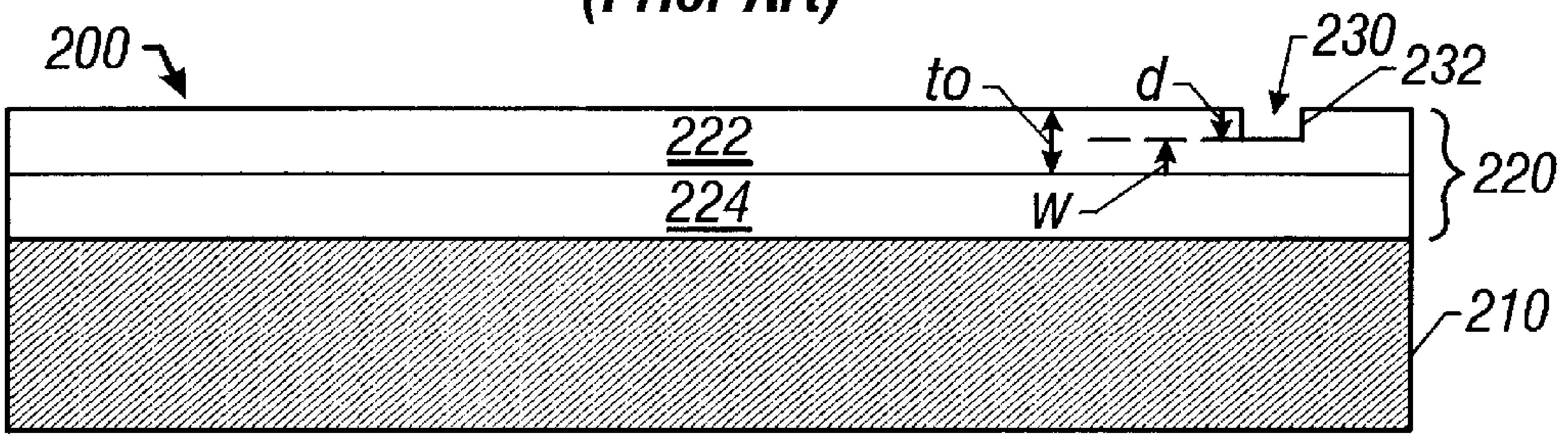

FIG. 2

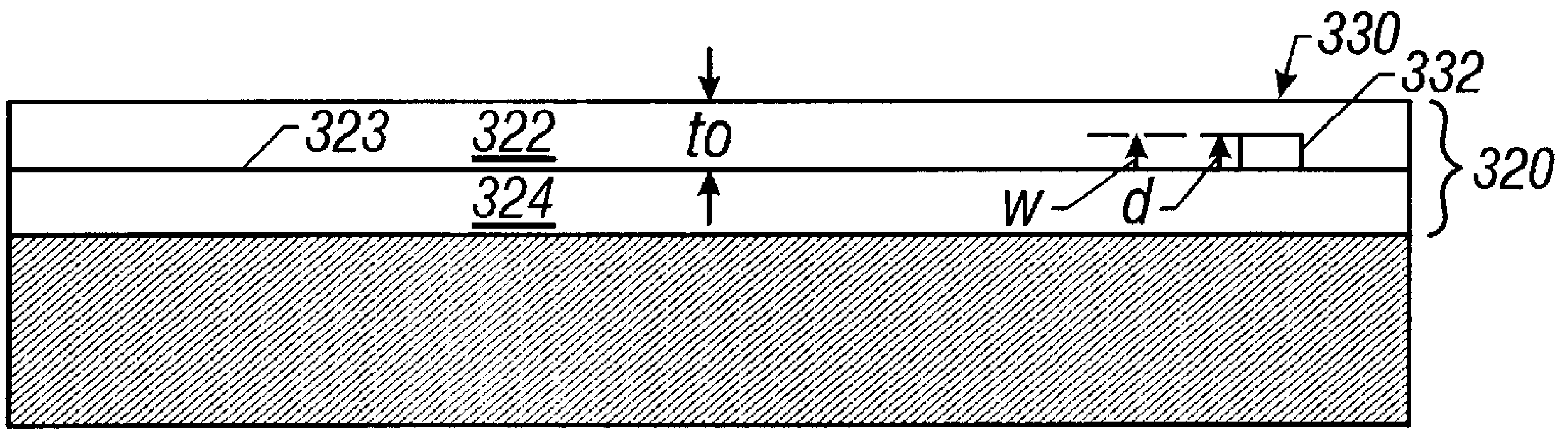

FIG. 3

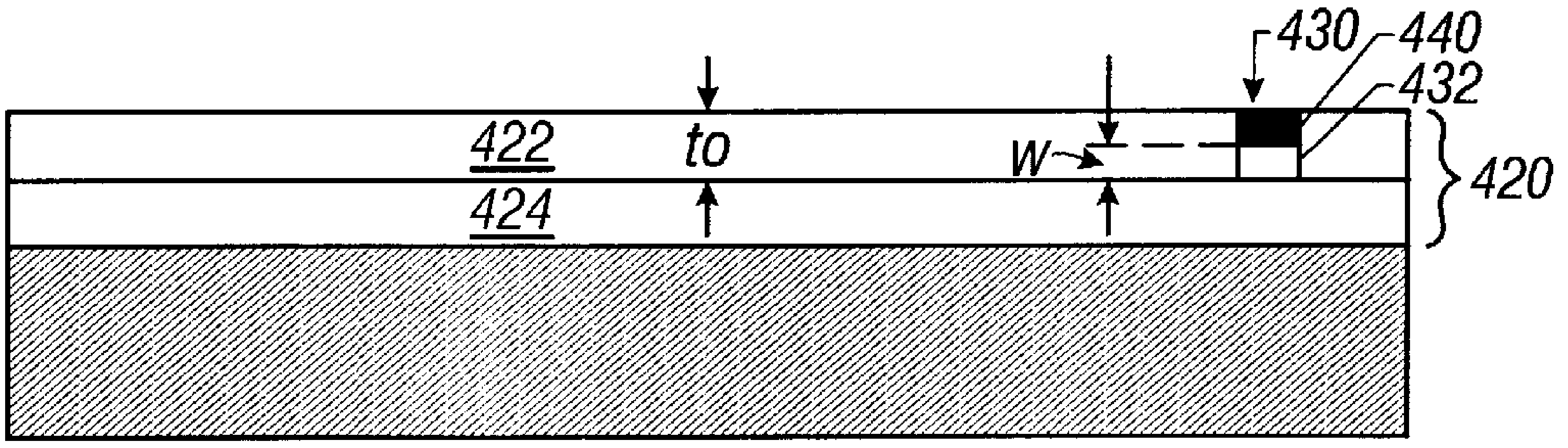

FIG. 4

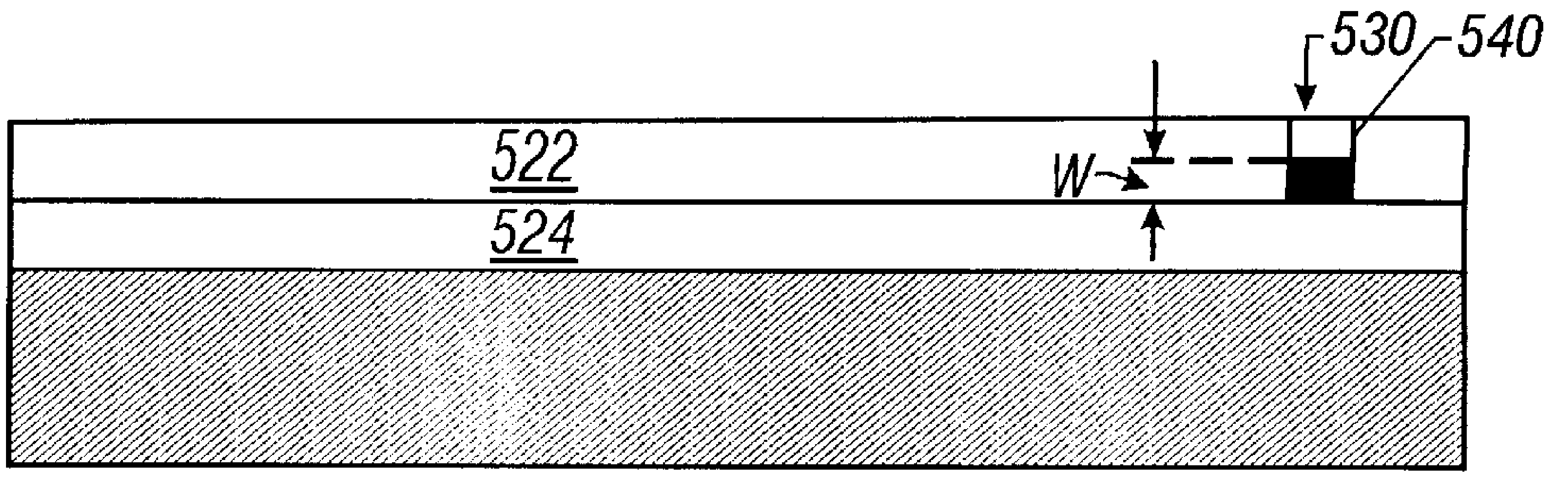

FIG. 5

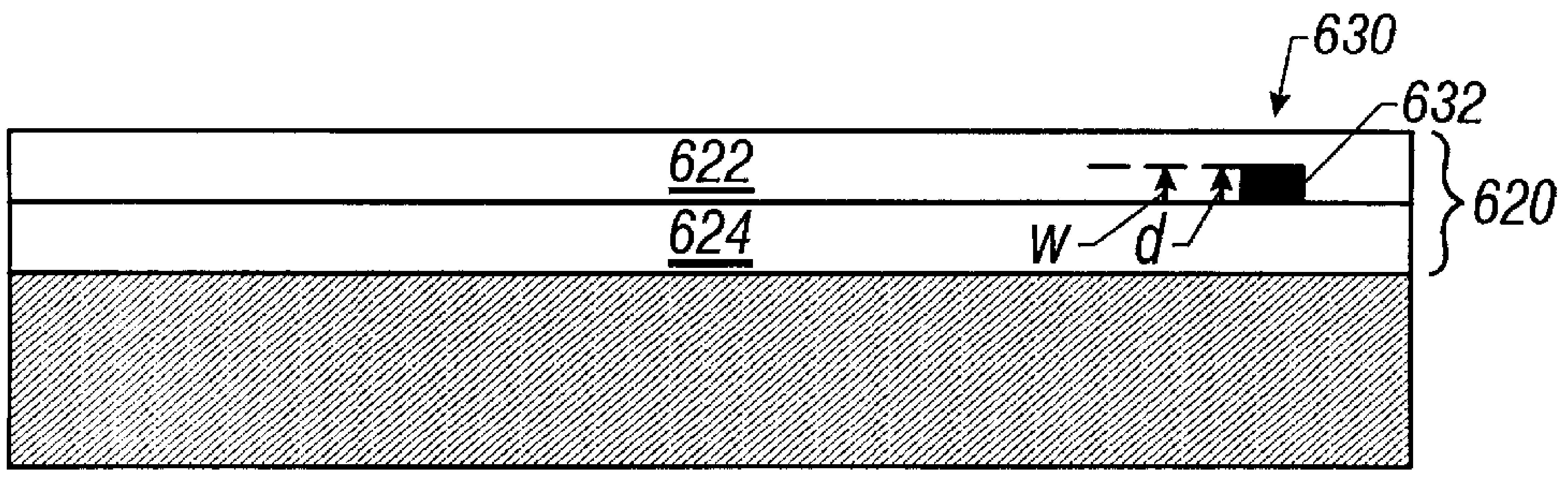

FIG. 6

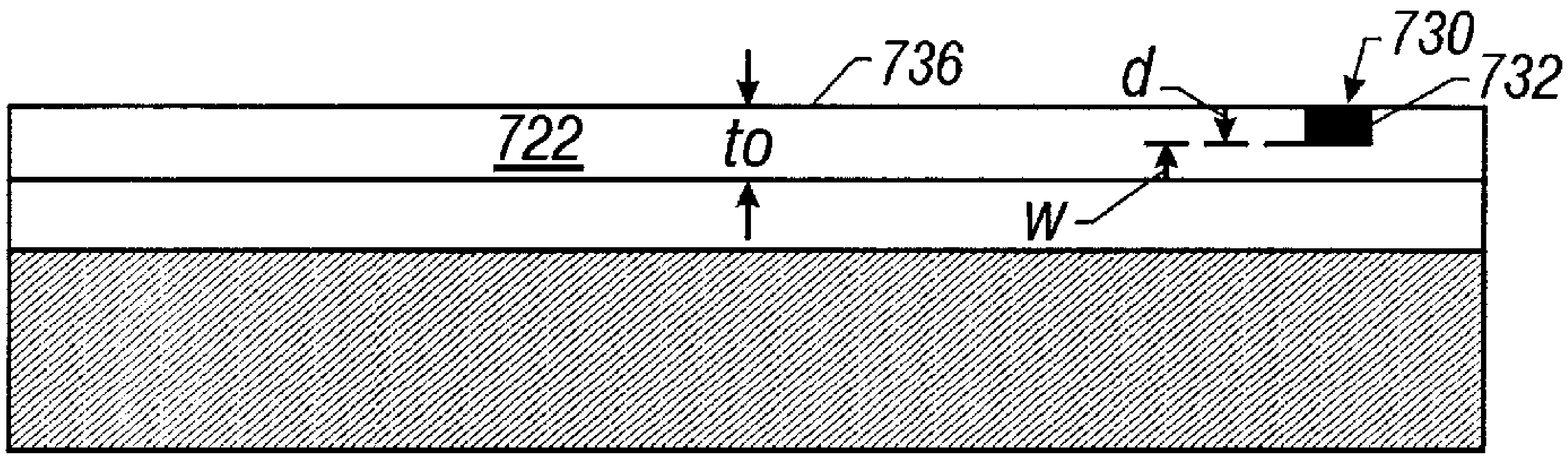

FIG. 7

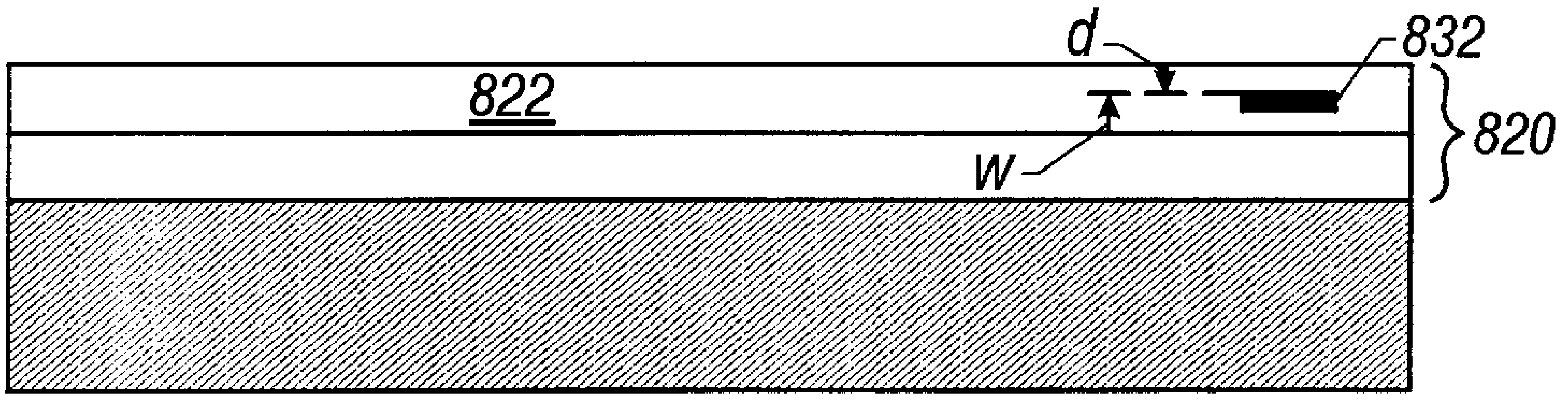

FIG. 8

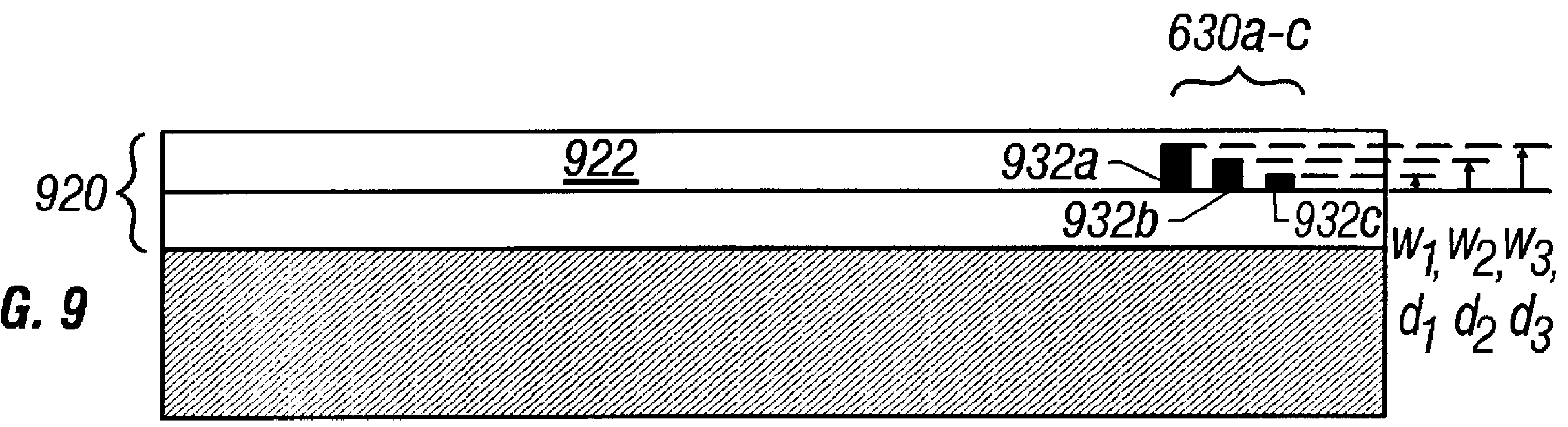

FIG. 9

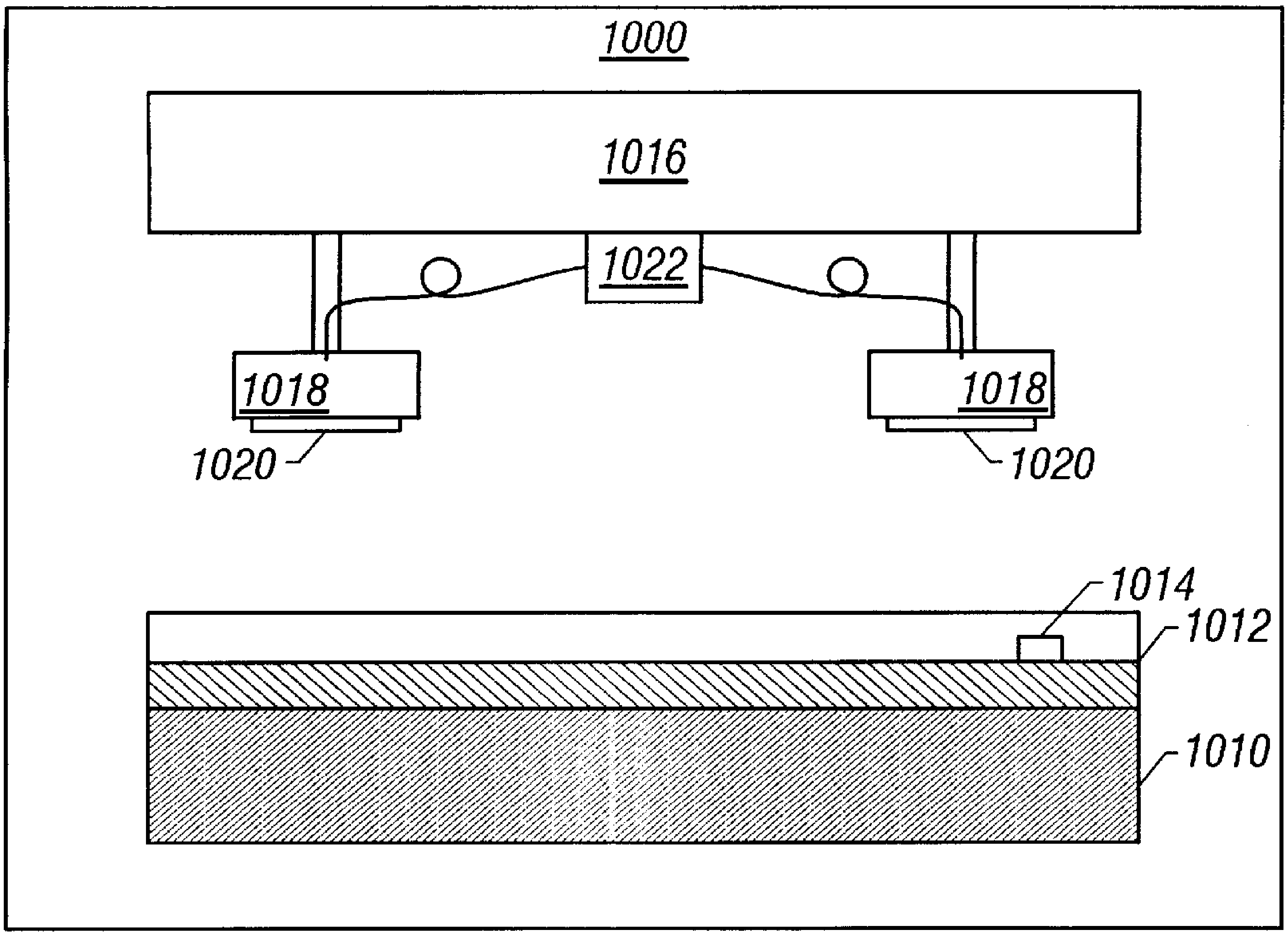

FIG. 10A

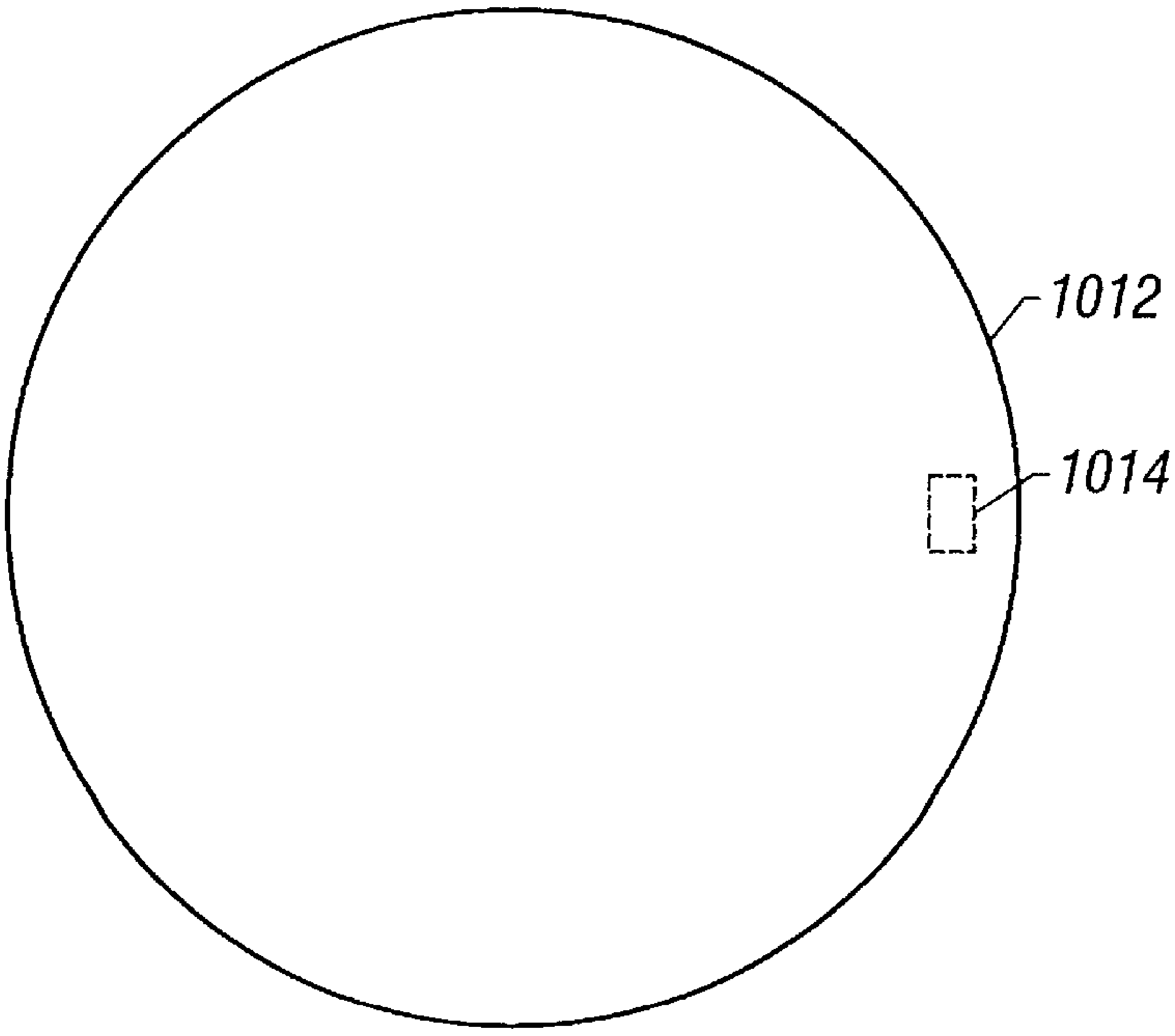

FIG. 10B

POLISHING PAD HAVING A WEAR LEVEL INDICATOR AND SYSTEM USING THE SAME

FIELD OF THE INVENTION

The present invention relates generally to the planarization of semiconductor wafers and, more specifically to a polishing pad having a wear level indicator and a system using the same.

BACKGROUND OF THE INVENTION

Chemical-mechanical polishing (CMP) is a widely used means of planarizing silicon dioxide as well as other types of surfaces on semiconductor wafers. Chemical mechanical polishing typically utilizes an abrasive slurry disbursed in an alkaline or acidic solution to planarize the surface of the wafer through a combination of mechanical and chemical action.

One type of chemical mechanical polishing system has a rotatable circular platen or table on which a polishing pad is mounted. A multi-head polishing device is positioned above the table. The polishing device has multiple rotating carrier heads to which wafers can be secured typically through the use of vacuum pressure. In use, the platen is rotated and an abrasive slurry is disbursed onto the polishing pad of the platen. Once the slurry has been applied to the polishing pad, the rotating carrier heads move downward to press their corresponding wafers against the polishing pad. As the wafer is pressed against the polishing pad, the surface of the wafer is mechanically and chemically polished.

FIG. **1** illustrates a typical polishing pad **120** shown mounted on a platen **110**. The polishing pad **120** includes a bottom pad **122** mounted on the platen and a top pad **124** mounted on the bottom pad. Typically, the top pad **124** is adhered to the bottom pad **122** using a glue. The bottom pad **122** serves as a damper and typically is formed from foam or felt. The top pad **124** generally contacts the wafer for polishing and is typically formed from polyurethane.

Polishing pads, such as the one described above, are engineered in an effort to maximize their planarization efficiency. Simultaneously, efficient, extended use of the pads generally requires pad conditioning between polishing runs. Conditioning typically includes applying a conditioning tool, such as a diamond impregnated steel plate, to the top pad to remove expired surface and expose fresh pad material. Repeated conditioning leads to thinning of the pad, a resultant decrease in the planarization efficiency and eventual end of useful pad life.

At present, a variety of methodologies are used to determine the appropriate time for a pad change. These include: number of wafers polished, number of pad condition hours, direct measurements of pad thickness. The first two methods are easily employed but prone to error due to the indirect nature of the measurements. The third method is inconvenient and labor intensive.

SUMMARY OF THE INVENTION

The present invention generally provides a polishing pad having a wear level indicator and a polishing system employing the same. The use of a wear level indicator allows for more efficient and reliable pad wear level indication than present methods. A polishing pad, in accordance with one embodiment of the invention, includes a pad structure and an indicator, disposed in the pad structure, indicating the wear level of the pad structure. The pad structure may, for example, include a top pad and a bottom pad with the indicator being disposed in the top pad. The wear level may, for example, be a critical thickness of the polishing pad which indicates the end of the pad lifetime or which indicates the need to change polishing processing.

The above summary of the present invention is not intended to describe each illustrated embodiment or implementation of the present invention. The Figures and the detailed description which follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. **1** is a cross-sectional view of a conventional polishing pad;

FIGS. **2–9** illustrate exemplary polishing pads in accordance with various embodiments of the invention; and

FIG. **10** illustrates an exemplary polishing system incorporating a polishing pad in accordance with one embodiment of the invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

The present invention is believed to be applicable to a number of types of polishing systems which employ polishing pads. The invention has been found to be particularly advantageous in indicating the wear level of polishing pads used in chemical-mechanical polishing. While the present invention is not so limited, an appreciation of various aspects of the invention will be gained through the discussion below.

FIGS. **2–9** illustrate exemplary polishing structures each having a polishing pad with a wear level indicator in accordance with an embodiment of the invention. By way of example, each illustrated polishing pad includes a dual-pad structure and is shown with a polish platen. In particular, the exemplary polishing pads each include a top pad in which a wear level indicator is disposed and a bottom pad which lies between the top pad and the polish platen. With the exception of the wear level indicator, the polishing pads and structures can, for example, be manufactured using well-known techniques such as those used to form the conventional polishing structure of FIG. **1**. For example, the top pads and bottom pads may be held together using an adhesive, such as glue. It is stressed, however, that the various polishing structures and pads discussed below are provided by way of example and not of limitation. The invention is applicable to any type structure having a polishing pad which is conditioned. For instance, polishing pads formed from any number of pads, including a single pad, are within the scope of the invention.

FIG. **2** illustrates an exemplary polishing structure in accordance with one embodiment of the invention. The polishing structure **200** generally includes a polish platen

210 on which a polishing pad **220** having top pad **222** with a wear level indicator **230** is mounted. In this particular embodiment, the wear level indicator **230** is a trench **232**, the depth d of which is set to indicate a predetermined wear level w of the polishing pad **220**. The trench **232** may be manufactured using a number of different techniques. The trench **232** may, for example, simply be formed by cutting out a portion of the top pad **222** to the desired depth. This may be done before or after the top pad **222** and bottom pad **224** are adhered together.

In operation, as the polishing pad **220** is conditioned, the thickness of the top pad **222** as well as the depth of the trench **232** will be reduced. Upon sufficient conditioning, the trench **232** will disappear, thereby indicating that the polishing pad **220** has reached its predetermined wear level w. The wear level w typically corresponds to a critical thickness of the pad, such as, for example, a thickness of the pad at which the pad has reached the end of its useful life or at which the polishing process must be changed based on the pad thickness. The wear level w can vary depending on, for example, the type of pad material and the polishing process used. Suitable wear levels w range from about 30% to 60% of the initial top pad thickness t_o for many applications. Accordingly, suitable trench depths d range from about 0.7 to 0.4 t_o.

FIG. **3** illustrates another embodiment of the invention in which a top pad **322** of a polishing pad **320** is provided with an inverted trench **332** as a wear level indicator **330**. In this particular embodiment, the trench **332** is cut out of the bottom surface **323** of the top pad **322**, typically prior to adhering the top pad **322** to the bottom pad **324**. In use, upon sufficient conditioning of the top pad **322**, the trench **332** will appear, thereby indicating the wear level of the polishing pad **320**. The depth d of the trench **332** is suitably selected in consideration of the desired wear level w of the top pad **332**. As indicated above, for many applications, the desired wear level w and thus the trench depth d ranges from about 30% to 60% of the initial top pad thickness to.

FIGS. **4** and **5** illustrate exemplary embodiments of the invention in which color inserts **432**/**532** are used as wear level indicators **430**/**530** of a polishing pad. In FIG. **4**, the top pad **422** of the polishing pad **420** includes a through-hole **440** in which a color insert **432** is disposed. The color insert **432** includes a lower portion **434** of one color and an upper portion **436** of a different color. In the illustrated embodiment, the lower portion **434** has a similar color as the bulk of the top polishing pad **422**, while the upper portion **436** has a readily distinguishable color. In use, the disappearance of the upper portion color and/or the appearance of the lower portion color indicates the desired wear level w of the top pad **422**. The interface **433** of the upper and lower portions **434** and **436** is typically set to the desired wear level w of the polishing pad **420**, and, depending on the application, may be located at about 30% to 60% of the initial thickness to of the top pad **422**.

The top pad **522** of FIG. **5**, similar to that of FIG. **4**, includes a through-hole **540** in which a color insert **532** is disposed. In this embodiment, the upper portion **534** has a similar color as the bulk of the polishing pad **522**, while the lower portion **536** has a readily distinguishable color. In use, the appearance of the lower portion color indicates the desired wear level w of the pad **522**. Alternatively, the lower portion **524** may include a dye cartridge which burst when subject to conditioning and spreads color dye over the top pad **522** to indicate attainment of the wear level w.

The color wear level inserts **432**/**532** may be formed from a number of different materials including, for example, polyurethane or felt. Typically, the color insert **532**/**432** is provided with an unstressed cross-sectional area slightly larger than the cross-sectional area of the hole **540**/**440** such that when inserted into the hole **40**/**440**, the color insert **532**/**432** is retained therein. The glue adhering the two pads **22**/**422** and **524**/**424** may also provide retention for the insert **532**/**432**. The hole **540**/**440** may, for example, be punched through the top pad **522**/**422** prior to adhering the top pad **522**/**422** to the bottom pad **524**/**424**.

FIGS. **6** and **7** illustrate embodiments of the invention in which partial color inserts **632**/**732** are used as wear level indicators **630**/**730** for a polishing pad. In FIG. **6**, a partial color insert **632** is disposed within a top pad **622** of a polishing pad **620**. The partial color insert **632** typically has a color which is readily distinguishable from the bulk of the top pad **622** and, in addition, typically has a depth d corresponding to the desired wear level w of the polishing pad, as discussed above. In use, upon sufficient conditioning of the top pad **622**, the color insert **632** will appear, indicating the particular wear level w of the polishing pad **620**. The color insert **632** may be provided using a number of different techniques. For example, the color insert **632** may be provided in the top pad **622** by cutting away part of the pad **622** and inserting the color insert **632** within the cutout trench. The color insert **632** may, for example, be formed from polyurethane and held within the trench by way of a snug fit (e.g., by providing the color insert **632** with an unstressed cross-sectional area greater than the cutout trench) as well as the glue between the top and bottom pads **622** and **624**. In an alternate embodiment, the color insert **632** may be a dye cartridge which bursts when subject to conditioning, thereby discoloring a large area of the pad and readily indicating the wear level w.

In FIG. **7**, a color insert **732** is provided in a trench **734** cut out of the top surface **736** of the polishing pad **722**. The partial color insert **732** may, for example, have a depth d (e.g., 40% to 70% of initial pad thickness to) equivalent to the desired wear level w, as discussed above. In use, upon sufficient conditioning, the color insert **732** will be removed and upon the absence of its color, the pad **722** will indicate its particular wear level w. The color insert **732** may, for example, be formed from polyurethane or felt and have an unstressed cross-sectional area slightly larger than the cutout trench **734**. This enables the partial color insert **732** to be held within the pad **722** by tightness of fit.

FIG. **8** illustrates an embodiment of the invention in which a color insert **832** functioning as a wear level indicator is embedded within a top pad **822** of a polishing pad **820** at a depth d equivalent to a desired wear level w. Typically, the color insert **832** is provided within the top pad **822** at the time of manufacturing to prevent localized thickness variation. For example, the top pad **822** may be formed from a polyurethane using a curing process. During the curing process, while the top pad **822** is still relatively flowable, the color insert **832** may be inserted into the polyurethane. In another embodiment, rather than using color insert **832**, the top pad **822** may be colored itself. This may be done, e.g., by simply coloring a polyurethane top pad **822** during the manufacturing process.

FIG. **9** illustrates an exemplary polishing pad having a series of graded indicators **930***a–c* indicating different wear levels $w_1 \ldots w_3$. In this particular embodiment, partial color inserts **932***a–c*, e.g., similar to the color insert discussed above with respect to FIG. **6**, are provided having different depths $d_1 \ldots d_3$ relative to the top pad **922** of the polishing pad **920**. As the polishing pad is conditioned, the color inserts **932***a–c* will appear at their set thicknesses $d_1 \ldots d_3$

to indicate the corresponding wear levels $w_1 \ldots w_3$. This provides an efficient way for indicating different thicknesses of the polishing pad **920**. The first two graded indicators **932***a* and *b* may, for example, be used to identify wear levels at which the polishing process must be changed. For example, at particular wear levels $w_1 \ldots w_2$ different parameters of the polishing process (e.g., length of time, slurry mix, wafer placement, etc.) may need adjusting. The final indicator **932***c* may, for example, then be used to indicate a wear level w_3 corresponding to the pad end of lifetime. While the graded indicators are illustrated through the use of a partial color insert similar to that of FIG. **6**, it should be appreciated that any combination of the aforementioned wear level indicators may be used to provide a graded indication scheme.

The wear level indicators illustrated above may be located at any of a number of positions in a polishing pad. Typically, the wear level indicators are located at a positions which have little or no effect on the polishing process. Suitable locations include, for example, areas of the polishing pad which remain unused throughout the polishing pad lifetime. Moreover, while only one wear level indicator or set of graded indicators is shown in each embodiment, it should be appreciated that additional wear level indicators or sets thereof may be placed about a polishing pad if desired. The use of multiple wear level indicators can, for example, increase the ability to detect localized regions of pad wear level.

FIGS. **10**A and **10**B illustrate an exemplary chemical-mechanical polishing system having a polishing pad with a wear level indicator. The CMP polishing system **1000** generally includes a platen **1010** on which a polishing pad **1012** having a wear level indicator **1014** is mounted. By way of example, a wear level indicator similar to that disclosed in FIG. **4** is provided. However, it should appreciated, any of the various wear level indicators may be used with a polishing system. The illustrated CMP system **1000** further includes a multi-head carrier **1016** positioned above the platen **1010**. The multi-head carrier **1016** includes a plurality of rotatable carrier heads **1018** on which semiconductor wafers **1020** can be secured using known techniques such as vacuum pressure. A source of polishing fluid **1022** is provided to supply polishing fluid to the pad **1012** for polishing While a multi-head chemical-mechanical polishing system is shown in the illustrative embodiment of FIG. **10**, as noted above, any type of polishing system using a polishing pad subjected to conditioning may be employed.

As noted above, the present invention is applicable to fabrication of a number of different types of polishing systems which employ polishing pads and would benefit from a polishing pad wear level indicator. Accordingly, the present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art upon review of the present specification. The claims are intended to cover such modifications and devices.

What is claimed is:

1. A polishing pad, comprising:

a pad structure having a polishing surface; and

a wear level indicator disposed in the pad structure for indicating a wear level of the pad structure, at least a portion of the wear level indicator being positioned adjacent the polishing surface.

2. The polishing pad of claim **1**, wherein the wear level corresponds to a thickness of the pad structure signifying an end of pad life.

3. The polishing pad of claim **1**, wherein the wear level corresponds to a thickness of the pad structure signifying a change in a polishing process.

4. The polishing pad of claim **1**, further including one or more additional indicators disposed in the pad structure for indicating the wear level of the pad structure.

5. The polishing pad of claim **4**, wherein the wear level indicators are disposed in the pad structure in a graded arrangement for indicating multiple wear levels of the pad structure.

6. The polishing pad of claim **1**, wherein the pad structure inlcudes a top pad and a bottom pad, the top pad being mounted on the bottom pad, the bottom pad being mountable on a platen.

7. The polishing pad of claim **1**, wherein the polishing structure includes a pad mountable on a platen.

8. The polishing pad of claim **1**, wherein the indicator includes a trench having an open end that is positioned adjacent the polishing surface of the pad structure.

9. The polishing pad of claim **8**, wherein the pad structure includes a top pad and a bottom pad, the trench being formed in the top pad.

10. The polishing pad of claim **1**, wherein the indicator includes a material having a different color than a surrounding portion of the pad structure.

11. The polishing pad of claim **10**, wherein the indicator is a portion of the pad structure having a different color than the surrounding portion of the pad structure.

12. The polishing pad of claim **10**, wherein the indicator is an insert, the insert including the material having a different color than the surrounding portion of the pad structure.

13. The polishing pad of claim **12**, wherein the differently colored material is disposed in a bottom portion of the insert away from the polishing surface of the pad structure.

14. The polishing pad of claim **12**, wherein the differently colored material is disposed in a top portion of the insert adjacent the polishing surface of the pad structure.

15. The polishing pad of claim **12**, wherein the pad structure includes a trench in which the differently colored material is disposed.

16. The polishing pad of claim **12**, wherein the pad structure includes a top pad and a bottom pad, the insert being disposed in the top pad.

17. The polishing pad of claim **16**, wherein the top pad defines a hole extending between the polishing surface and a bottom surface of the top pad, the insert being disposed within the hole.

18. The polishing pad of claim **17**, wherein the insert adheres to an upper surface of the bottom pad.

19. The polishing pad of claim **16**, wherein the top pad includes a trench in the polishing surface opposite the bottom pad, the insert being disposed in the trench.

20. The polishing pad of claim **19**, wherein the insert is frictionally fit into the trench.

21. The polishing pad of claim **1**, wherein the wear level indicator is a dye cartridge.

22. A system for polishing semiconductor wafers, comprising:

a polishing platen;

a motor for rotating the polishing platen;

a polishing pad mounted on the polishing platen, the polishing pad including an indicator disposed in the polishing pad for indicating a wear level of the polishing pad, at least a portion of the indicator being positioned adjacent a polishing surface of the polishing pad; and

a source of polishing fluid adapted for providing polishing fluid to the polishing pad.

23. The polishing system of claim **22**, wherein the polishing pad includes a top pad and a bottom pad, the indicator being disposed in the top pad.

24. The polishing system of claim **23**, wherein the polishing pad further includes additional indicators disposed in the polishing pad for indicating the wear level of the pad structure.

25. The polishing system of claim **24**, wherein the wear level indicators are disposed in the pad structure in a graded arrangement for indicating multiple wear levels of the polishing pad.

26. The polishing system of claim **24**, wherein the wear level indicators are positioned in spaced apart locations of the polishing pad and a plurality of the wear level indicators have a similar grade for indicating a common wear level at the spaced apart locations of the polishing pad.

27. The polishing pad of claim **1**, wherein the wear level indicators are positioned in spaced apart locations of the polishing pad and a plurality of the wear level indicators have a similar grade for indicating a common wear level at the spaced apart locations of the polishing pad.

28. A polishing pad, comprising:

a pad structure having a polishing surface; and

at least one trench disposed in the polishing surface of the pad structure for indicating a wear level of the pad structure, the trench having an open end that is positioned adjacent the polishing surface.

29. The polishing pad of claim **28**, wherein the at least one trench has a depth that corresponds with a predetermined wear level of the polishing pad.

30. The polishing pad of claim **28**, wherein the pad structure includes a top pad and a bottom pad, the top pad being mounted on the bottom pad, the bottom pad being mountable on a platen.

31. The polishing pad of claim **28**, wherein a plurality of trenches are disposed in the polishing surface of the polishing pad, and the plurality of trenches have varied depths for indicating multiple wear levels of the polishing pad.

32. The polishing pad of claim **28**, wherein a plurality of trenches are disposed in spaced apart locations of the polishing surface of the polishing pad, the plurality of trenches having a similar depth for indicating a common wear level at the spaced apart locations of the polishing pad.

33. A polishing pad, comprising:

a pad structure having a polishing surface; and

at least one insert disposed in the pad structure for indicating a wear level of the pad structure, at least a portion of the at least one insert having a different color than a surrounding portion of the pad structure, and at least a portion of the at least one insert being positioned adjacent the polishing surface.

34. The polishing pad of claim **33**, wherein the differently colored portion of the at least one insert is positioned in a bottom portion of the insert away from the polishing surface of the pad structure.

35. The polishing pad of claim **34**, wherein the differently colored portion of the at least one insert represents a predetermined wear level of the pad structure.

36. The polishing pad of claim **33**, wherein the differently colored portion of the at least one insert is positioned in a top portion of the insert adjacent the polishing surface of the pad structure.

37. The polishing pad of claim **36**, wherein at least a portion of the at least one insert has a color that is similar to the surrounding portion of the pad structure, and the similarly colored portion of the at least one insert represents a predetermined wear level of the pad structure.

38. The polishing pad of claim **33**, wherein a plurality of the inserts are disposed in the polishing pad, and the differently colored portions of the plurality of inserts are located in different positions on the inserts for indicating multiple wear levels of the polishing pad.

39. The polishing pad of claim **33**, wherein a plurality of the inserts are disposed in different locations of the polishing pad, and the differently colored portions of the plurality of inserts are located in similar positions on the inserts for indicating a common wear level at the different locations of the polishing pad.

40. A method comprising:

conditioning a polishing pad having a wear level indicator disposed therein, at least a portion of the wear level indicator being positioned adjacent a polishing surface of the polishing pad; and

determining a wear level of the polishing pad based on changes in the wear level indicator.

41. The method of claim **40**, further comprising replacing the polishing pad with a new polishing pad once the wear level of the polishing pad has increased beyond a predetermined threshold.

42. The method of claim **40**, further comprising adjusting a processing parameter of a polishing process based on a predetermined wear level of the polishing pad.

* * * * *